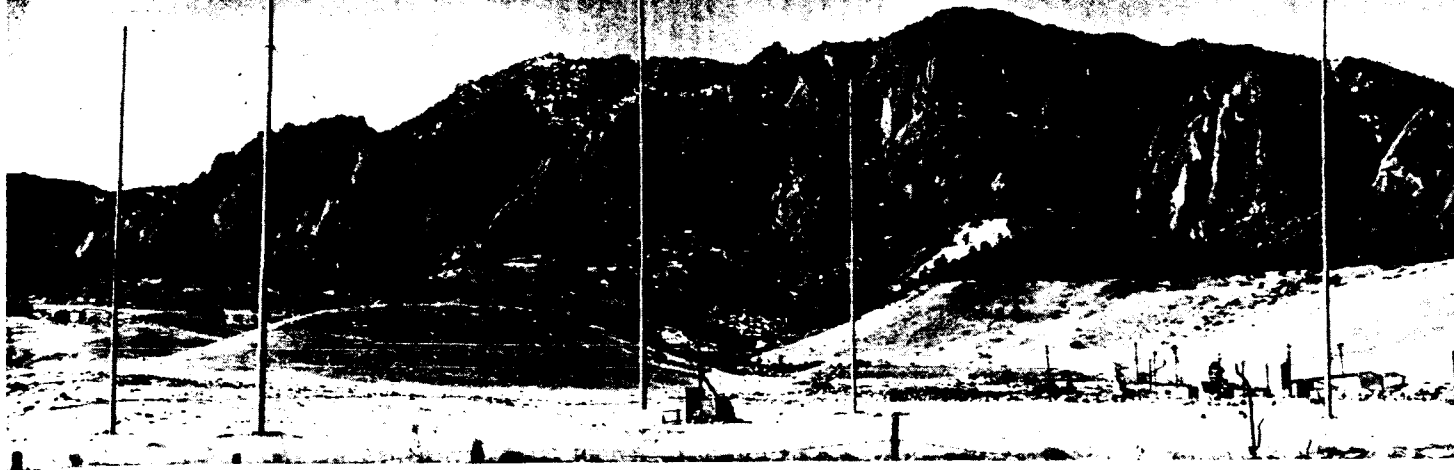


EXPERIMENTAL STANDARD FREQUENCY BROADCAST ON 60 KILOCYCLES



AN EXPERIMENTAL 60-kc standard frequency broadcast, begun July 1, 1956, at the Boulder (Colo.) Laboratories of the Bureau, is opening up several interesting applications, some of which are already in use. A. H. Morgan, Chief of the Radio Broadcast Service Section of the NBS Radio Standards Laboratory, is supervising the experiment.

The Bureau has been broadcasting standard frequencies since 1923, when radio was in its infancy and very few people owned radio receivers. Through the years higher power and more frequencies have been added until at present the NBS standard frequency broadcasts are on six high frequencies (2.5, 5, 10, 15, 20, and 25 Mc) at WWV, Beltsville, Maryland; and on three (5, 10, and 15 Mc) at WWVH, Maui, Territory of Hawaii. Up to 10 kw are radiated on some of the frequencies. Specialized radio receivers for these broadcasts have been commercially available for many years.

Measurements by the Boulder Laboratories and others have revealed that the regular standard broadcasts at high frequency (HF) are subject to changes in frequency as they travel away from the transmitting antenna. These changes are caused by disturbances in the propagation medium, and the errors introduced may at times amount to ± 3 parts in 10^7 . This is sufficient to make these HF broadcasts unsuitable for many applications, e. g., rapid assessment of drift in the manufacture of high-precision quartz resonators, intercomparison of frequency standards, and accurate time measurement or synchronization of events at two or more locations which may be separated by thousands of miles. Two techniques are now available for precise frequency calibration, but both have limitations. One such technique, employing time comparisons, requires expensive terminal apparatus and a measurement

Antenna structural used by the Bureau for experimental standard frequency broadcast at 60 kc. The location is about 1 mile east of the Flatiron Mountains, a part of the front range of the Rocky Mountains. Five 125-foot poles, one on each corner of a square and one in the center, support the wires of the antenna. Tuning house is near the center pole.

time that extends over 1 to 10 days or even longer. The other makes use of a ground wave near the transmitter. This introduces an error in propagation of less than 1 part in 10^{11} , but is useful only to about 20 miles from the transmitter. At distances of greater than 20 miles the skywave must be used, and calibrations made by means of this wave are not adequate for the ever increasing precision required by an expanding science and technology.

To meet this urgent situation, W. D. George, Acting Chief, Radio Standards Laboratory, initiated a plan to begin the experimental broadcasts at several low or very low frequencies. The 60-kc frequency is being put into use first under the call sign, KK2XEI.

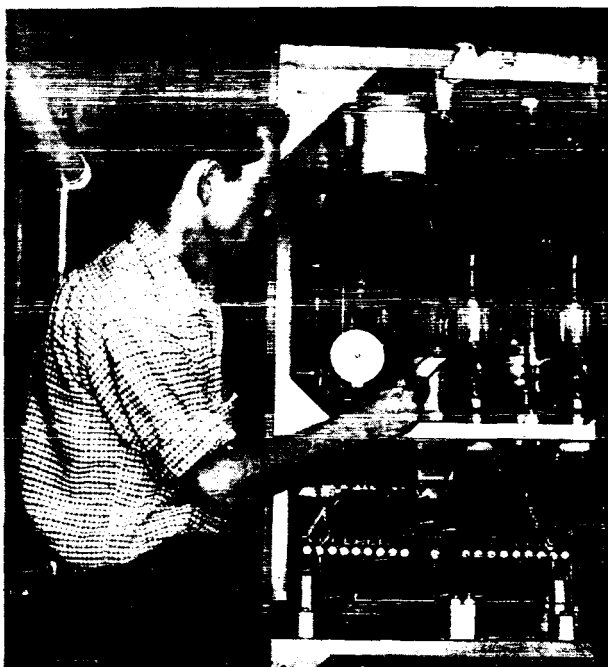
The principal reason for studying standard frequency broadcasts at frequencies below about 100 kc is to determine a practical method whereby the radio propagation errors are minimized and users may accomplish high-accuracy frequency comparisons in a shorter measurement time. Users also need a better time or phase reference to precisely measure the time between events that happen in relatively short intervals, for example, in measuring the velocity of rapidly moving waves or objects.

Several investigators, among them Professor J. A. Pierce at Harvard University, have shown that for frequencies below 100 kc and for distances of 5,000 km and greater, it requires only about 10 min to compare local frequencies with standard frequency transmissions to within 1 part in 10^9 . This is an



Above: Interior of the tuning house near the antenna base, showing the tuning coils used in efficiently transferring power from the transmitter (about 3,000 ft away) via an overhead transmission line to the antenna.

Below: John Milton of the NBS Boulder Laboratories points to a 2,000-w output amplifier in the experimental 60-kc transmitter. Control frequency from the national standard is fed to the transmitter via a 1,500-ft transmission line.



improvement of more than 100 over what can be obtained at HF. Professor Pierce has carefully determined that a high-accuracy standard frequency service can be given for all the world on a single very low frequency from a single high-power transmitter.¹

The experimental broadcast on 60 kc, although on low power, has already presented several intriguing possibilities. With the cooperation of Professor Pierce, it has been possible to compare the NBS primary frequency standard, broadcast on 60 kc, with the British standard which is broadcast on 16 kc and 60 kc, to an accuracy of comparison that is better than 2 parts in 1 billion. This has been done almost continuously since the broadcasts began last July. Results for the month of January 1957 are shown in table 1. Regular measurements on the 60-kc broadcast are now being made by several groups in the eastern United States.

The most challenging project will be an attempt to compare the Boulder Laboratories' atomic-frequency standard, which is much more stable than 1 part in 10^9 , with those in England and elsewhere. This will be undertaken as soon as possible. It is estimated that an accuracy of comparison of better than 1 part in 1 billion can be attained.

Tests with the experimental low-frequency standard broadcast will provide information not only on the ultimate stability of the received waves, but on possible ways of improving the standard frequency broadcast services. A high-power VLF station would be very expensive but probably less so than a network of HF or VHF stations which would be needed to give a frequency and phase standard of high accuracy at all times and places on the earth.

¹ Intercontinental frequency comparison by VLF radio transmission (*Proc. IRE, Special VLF issue to be published in 1957*).

TABLE 1. Comparisons of 60-kc experimental broadcast, Station KK2XEI

(Values given are parts in 10^9)

Date (1957)	Versus NBS Standard at Boulder	Versus GBR measurements made at Craft Lab.	Versus WWV average over 10 days as received at Boulder	Versus WWV as received at Craft Lab.
Jan. 2	-0.3	-1.4	+1.0	+2.2
3	+0.2	-2.1	+1.5	+2.2
4	+0.3	-2.3	+1.7	+0.7
7	+0.7	...	+2.3	...
8	-0.1	...	+1.5	...
9	-0.3	-3.7	+1.4	+0.4
10	+0.3	...	+2.1	...
11	+0.5	-2.4	+2.3	-0.9
14	0	-1.8	+2.0	+1.0
15	+0.1	-1.4	+2.1	+1.6
16	0	-1.1	+2.2	+1.1
17	+0.1	-0.8	+2.4	+2.6
18	0	-1.5	+2.3	+2.8
21	+0.8	-1.4	+2.7	+2.6
22	+0.3	-0.5	+2.1	+1.7
23	+0.4	-0.3	+2.4	+2.4
24	+0.5	-0.9	+2.4	+2.9
25	+0.1	-1.8	+2.0	...
28	-0.3	-2.4	+1.4	...
29	+0.1	-1.9	+1.8	...
30	-0.2	-2.9	+1.4	+1.7
31	-0.2	-2.4	+1.4	+1.2
Feb. 1	0	-2.6	+1.5	+1.7